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NORMAL DURATION OF THE ELECTRIC SYSTOLE IN MAN

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It has long been known that the duration of the Q-T interval of the electrocardiogram, conventionally referred to as the electric systole, depends on the cardiac rhythm, in other words, on the length of the cardiac cycle. The dependence of the duration of the Q-T interval* on the frequency of the cardiac contractions was first described mathematically by two authors, Fridericia [1] and Bazett [2], working independently. Fridericia expressed this dependence /1472

by means of an equation in which $S_e = 8.22 \sqrt[3]{C}$ (S_e and C in hundredths of a second); according to Bazett, $S_e = K \sqrt{C}$ (K for men is 0.37 and for women 0.40). Both these formulas are exponential functions of the type:

$$S_e = aC^n, \qquad (1)$$

differing only with respect to the value of the exponent (according to Fredericia n = 1/3, according to Bazett n = 1/2) and the constant coefficient a.

Somewhat later, Adams [3] arrived at the conclusion that the mathematical description of the interrelationship between the duration of the Q-T interval and the length of the cardiac cycle does not require the use of curves of this order. He described the relation between S_e and C by means of a linear equation: $S_e = 0.1464$ C + 0.2572. Ashman [4], on the other hand, proposed a complex logarithmic formula for calculating the duration of the Q-T interval.

These basic types of formulas have recently been subjected to numerous experimental checks, as a result of which the authors

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*Henceforth, the duration of the Q-T interval will be denoted by S_e.

have introduced certain corrections. Now the number of formulas describing the interrelationship between S_e and C has considerably increased (the majority is reviewed in [5-7]). The present investigation was undertaken with the object of establishing, on the basis of a sufficiently large number of observations, which of the proposed formulas is best fitted for calculating the duration of the Q-T interval corresponding to a given cardiac rhythm.

Nature of the observations.

The work is based on an analysis of the electrocardiograms of 307 more or less healthy individuals, including 186 men and 121 women. The age of those examined varied between 17 and 59. The distribution among age groups was as follows:

17-19	20-29	30-39	40-49	50-59
19	116	103	51	18

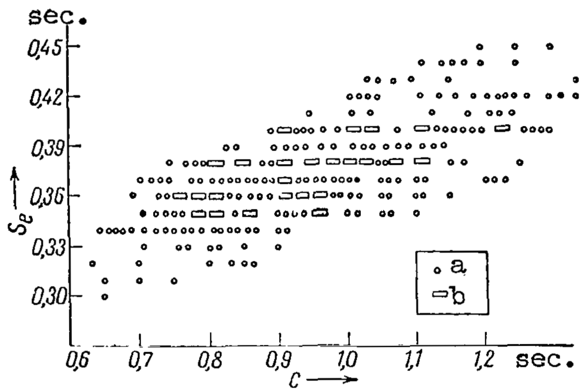
The electrocardiograms analyzed were recorded for standard electrode arrangements, with the subject reclining in a horizontal position after a 10-15 minute rest. The electrocardiograms were registered on a five-channel photorecording electrocardiograph.

Where different electrode arrangements gave different values of the Q-T interval, the duration of the electric systole was determined from the maximum value of the interval. Observations where the end of the T spike could not be clearly distinguished owing to superimposition of the U spike [8, 9] were not included in the group /1473
analyzed.

The cardiac rhythm of the subjects varied between 94 and 46 per minute. 62 displayed bradycardia, 3 slight tachycardia, and the rest had heart beats of normal frequency.

Results

The relationship between the duration of electric systole and cardiac rhythm, as we observed it, is shown in Fig. 1. In order to obtain a mathematical description of this relationship and express it by means of a suitable formula, all our observations were divided into 7 groups, for each of which we computed the mean duration of the cardiac cycle and the mean duration of electric systole



[Commas represent decimal points]

Fig. 1. Duration of Q-T interval (S_e) as a function of duration of cardiac cycle (C) for 307 more or less healthy individuals. a - 1 observation, b - 5 observations.

(Table 1). Employing the coordinate system S_e, C (Fig. 2), we used the average data thus obtained to plot points characterizing the normal relationship between the duration of electric systole and the duration of the cardiac cycle in the healthy individuals we had investigated. On the basis of these points we constructed a curve which we attempted to describe by means of a power function of type (1). The value of the coefficient a in formula (1) was found from the average value of S_e for C = 1. According to our observations, a = 0.383. The value of the exponent was determined empirically as follows. Using equation (1), we constructed a family of curves with values of n varying from 0.3 to 0.5. It was found that n = 0.33 gives the best agreement between the theoretical curve and the experimental points. Thus, equation (1) may be written in the following form:

$$S_e = 0.383\, C^{0.33}. \tag{2}$$

or, which amounts to the same thing,

$$S_e = 0.383 \sqrt[3]{C}. \tag{3}$$

From the data presented in Table 1 it follows that the values computed from equation (3) agree sufficiently well with the experimental values.

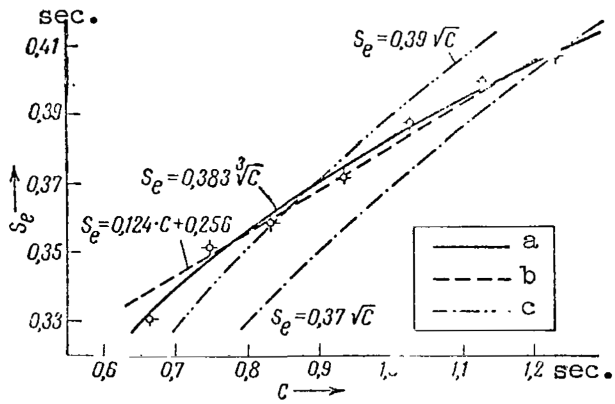
Table 1.

Duration of cardiac cycle, sec.		No. of subjects	S_e, experim. sec.	S_e theor., sec.	
interval	mean			$S_e = 0.383 \sqrt[3]{C}$	$S_e = 0.124C + 0.256$
0.6-0.69	0.665	9	0.331	0.332	0.338
0.7-0.79	0.748	43	0.352	0.348	0.349
0.8-0.89	0.834	60	0.359	0.360	0.359
0.9-0.99	0.936	75	0.372	0.374	0.373
1.0-1.09	1.028	53	0.388	0.386	0.383
1.1-1.19	1.129	39	0.400	0.399	0.397
1.2-1.29	1.230	28	0.408	0.410	0.409

Taking into account the fact that over the range of variation of the argument from 0.64 to 1.3 seconds the curvature of the function is small, we proceeded to linearize equation (3). We then obtained the following linear equation:

$$S_e = 0.124C + 0.256. \quad (4)$$

As shown in Table 1, and in Fig. 2 which serves to illustrate it, the experimental value of S_e and C is satisfactorily described by equation (4) as well. When individual values of the duration of



[Commas represent decimal points]

Fig. 2. Actual duration of Q-T interval (S_e) compared with the theoretical for a given cardiac rhythm. Circles - mean experimental values of duration of Q-T interval (see Table 1). a - based on formula (3), b - based on formula (4). For the sake of comparison we have included curves (c) based on the formulas of Bazett [2] ($S_e = 0.37\sqrt{C}$) and Hegglin-Holzmann [12] ($S_e = 0.39\sqrt{C}$).

the Q-T interval were compared with those calculated from equations (3) and (4), it proved that the overwhelming majority of the observations fluctuated about the theoretical values within the limits $\pm$ 0.04 seconds. A two-year experiment (begun in 1962), involving the application of equations (3) and (4) to the work of our own laboratory, showed their effectiveness in evaluating a functional state of myocardia in sick and healthy individuals. /1474

An analysis of our equation (3) shows that if the values of S_e and C are expressed in hundredths of seconds, it assumes the form: $S_e = 8.26\sqrt[3]{C}$. Hence, our data are almost exactly described by the equation proposed more than 40 years ago by Fridericia. Furthermore, it turned out that our experimental points can also be sufficiently accurately approximated by the classical equation of a parabola, the coefficients of which were selected [10] after the analysis of a large number of electrocardiograms.

Further analysis of our results showed that the formula proposed by Bazett [2] and then refined by Hegglin and Holzmann [11], though the one most frequently used in cardiology, does not satisfactorily describe our observations (Fig. 2).

It seems to us that the inaccuracy of Bazett's formula is due to the extremely small number of observations (39 individuals) on which his correlation series is based.

A comparison of equation (4) with those to be found in the literature revealed its similarity to the linear formula recently derived by Simonson et al. [7]. The curves expressing the interrelationship between S_e and C based on the linear formulas of other authors [12-14] are steeper. They do not give a satisfactory description of our observations.

The question arises whether it is possible to use our improved equations for expressing the relation between duration of electric systole and duration of the cardiac cycle over the entire range of frequencies of the cardiac rhythm and, in particular, at the high tempos of cardiac activity observed in connection with physical stress, emotional states, fever, etc.

Although we do not have the corresponding data available, we also consider it incorrect to use a fixed set of equations to describe this dependence no matter whether the values of the cardiac cycle are large or very small, as has been done by certain investigators [11].

In all probability, the various chrono- and inotropic influences on the heart in the presence of physical stress and the other states mentioned above may affect the relation between the duration of the cardiac cycle and the duration of electric systole.

Accordingly, we assume that in the region of small values of C the interrelationship between S_e and C should be described by an independent equation, different from that obtained for values of C prevailing under conditions of repose in the normal state of the organism.

In conclusion, we should mention the question of the dependence of fluctuations in the duration of electric systole on sex and age. The literature on this subject is conflicting. Some authors have found a clear dependence of the duration of electric systole on sex [2, 10], others have failed to find any significant differences in the duration of the Q-T interval as between men and women [11, 15]. According to our data, other things being equal, electric systole lasts, on the average, 0.01 second longer in women than in men. On the other hand, contrary to the suggestions in the literature [7, 15] that the Q-T interval increases with age, we failed to detect any such increase in our observations embracing the ages from 17 to 59 years. /1475

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